HYDRAULIC RELEASE RUNNING TOOL

DESCRIPTION

FIELD OF INVENTION

[Para 1] The invention relates to hydraulic release running tools for setting rotatable liner hangers; and more particularly to running tools having a secondary mechanical release and backlash relief.

BACKGROUND OF THE INVENTION

[Para 2] Running tools are used in combination with liner hangers in wellbore drilling and completion operations. Following drilling of at least a segment of a wellbore, casing is positioned into the open hole and cemented into place. Drilling is continued below the cemented casing to extend the depth of the wellbore. At least a second length of smaller diameter casing is lowered into the extended wellbore on a tubing string equipped with a releasable running tool and a liner hanger. Mechanical release running tools are often used for vertical wellbores. Hydraulic running tools are often preferred for high angle and horizontal wells due to increased difficulty in relying on mechanical manipulation to release the running tool from the liner hanger once properly located.

[Para 3] Running tools are required to securely support the liner yet also be reliably releasable. The conditions of liner installation introduce non-trivial challenges for a running tool. To install liner, a liner hanger assembly of a liner hanger and a considerable weight of depending liner is hung from a releasable running tool. The running tool is run in downhole until the liner

hanger is adjacent a distal end of the last cemented casing. Liner hanger slips are actuated to grip the walls of the existing casing and support the substantial weight of the depending liner until such time as the new liner can be cemented into place. This is repeated as often as necessary, each liner then becoming the casing supporting subsequent liners. It is also known to rotate the liner, not only during insertion into the wellbore, but also after setting of the liner hanger slips. Depending upon the circumstances, it may be advantageous to rotate the liner during cementing such as to ensure a uniform distribution of cement in the casing annulus as well as proper displacement of the drilling mud, without channeling of the cement through the mud. The running tool is required to enable rotation without releasing prematurely.

[Para 4] Once located downhole, pressure in the bore of the tubing string is increased to actuate the liner hanger and set the slips to the casing. The weight of the liner is now hanging from the liner hanger and distal end of the casing. Fluid communication is established from the tubing string to the wellbore and a pre-determined volume of cement is pumped out through a float shoe. The liner may be rotated through rotation of the tubing string and running tool. Drilling fluid is displaced up a casing annulus until the cement finally reaches the liner hanger. Cementing is then stopped, after which the running tool is released from the liner hanger and removed from the well.

[Para 5] To avoid catastrophic circumstances should the running tool fail to release by the completion of cementing, it is preferably to pre-release the running tool from the liner hanger prior to cementing. Accordingly, the running tool must not release prematurely such as during running and setting of the liner hanger nor during preparation for cementing. Further, the running tool must resist significant backlash forces which can result from the rotating liner installation. Additionally, in the case of hydraulic running tools, should the hydraulic release fail, it is preferably to have some backup means for releasing the tool from the liner hanger.

SUMMARY OF THE INVENTION

[Para 6] In one embodiment of the invention, apparatus is provided for hydraulic release of a running tool from a downhole tool such as a liner hanger. In another embodiment, secondary apparatus is provided for mechanical release actuation of components of the hydraulic release as a backup. In yet another embodiment, a latch for releasably supporting a mandrel in a tubular tool is provided In yet another embodiment, a clutch is provided and in another embodiment the clutch is integrated with a running tool for avoiding accidental actuation of the secondary mechanical release apparatus. In an embodiment of the clutch, a ratchet is provided.

[Para 7] Accordingly, in one broad aspect of the invention, a running tool is adapted to releasably support a downhole tool comprising: a hydraulic release, a mandrel having a bore and a locking cylinder movable axially over the mandrel and forming a piston annulus therebetween, a port being formed between the bore and the piston annulus, the locking cylinder having an uphole end; a piston in the piston annulus and whose movement is axially delimited between an uphole stop on the mandrel and a downhole stop on the locking cylinder sleeve, the port being positioned axially between the uphole stop and the piston; a latch cage positioned uphole of the locking cylinder and being movable axially on the mandrel between an engaged position and a disengaged position, the latch cage having two or more latch segments which are supported axially and movable radially so that when the latch cage is in the engaged position, the latch segments are supported in a radially extended position to engage with and axially support the downhole tool, and in the disengaged position, the latch segments are released to a radially recessed position to disengage from the downhole tool; and two or more latch shoulders positioned downhole of the latch cage for axially supporting the latch cage in the engaged position, the latch shoulders being temporarily retained radially to the mandrel by the uphole end of the locking cylinder, so that pressure applied at the port, hydraulically drives the piston downhole to engage the downhole stop, moving the uphole end of the locking cylinder downhole to release the latch shoulders from the mandrel and permitting the

latch cage to move axially to the disengaged position for releasing the latch segments from the downhole tool.

[Para 8] Preferably, in another aspect of the invention, a secondary mechanical release is provided further comprising: an uphole drive housing fit about the mandrel and uphole from the latch cage wherein the drive housing is co-rotatable with the mandrel and has a drive face adapted for rotational drive coupling with the downhole tool, the mandrel being releasably supported on the drive housing; and means for releasing the mandrel for axial movement through the drive housing and for manipulation through the latch cage so as to shift the latch cage and latch segments relatively uphole to the disengaged position. Preferably, a temporary axial restraint, such as circumferentially space profiles between the drive housing and the mandrel which are alternatively selected using a J-slot, exists between the latch cage and the mandrel. The temporary axial restraint is overcome by relative movement of the downhole tool and the mandrel.

[Para 9] Accordingly, in yet another aspect of the invention, a rotational clutch is provided between the mandrel and the uphole drive housing wherein a ratchet annulus is formed between the mandrel and the uphole drive housing, the tool further comprising: an external mandrel spline extending radially outwards from the mandrel into the ratchet annulus; an internal housing spline extending radially inwards from the uphole drive housing into the ratchet annulus; and a barrel ratchet residing in the ratchet annulus and having internal teeth extending radially inward from a body and external teeth extending radially outward from the body, the body being flexible for enabling the internal teeth and external teeth to move radially in the annulus and alternate between locking the mandrel spline and housing spline for co-rotation in a driving direction and releasing the mandrel spline and housing spline in a ratcheting direction, wherein the body of the barrel ratchet flexes to lock the mandrel spline and housing spline for co-rotation in a driving direction, and the barrel ratchet flexes to separate at least one of the barrel ratchet's internal or external teeth from the mandrel spine or housing spline

respectively to release the mandrel spline and housing spline and enable relative rotation.

[Para 10] In another broad aspect of the invention, a ratchet for enabling uni-directional torque comprises: a mandrel and a housing forming an annulus therebetween, the mandrel having an external spline extending into the annulus and the housing having an internal spline extending into the annulus; and a barrel ratchet residing in the ratchet annulus and having internal teeth extending radially inward from a body and external teeth extending radially outward from the body, the body being flexible for enabling the internal teeth and external teeth to move radially in the annulus and alternate between locking the mandrel spline and housing spline for co-rotation in a driving direction and releasing the mandrel spline and housing spline in a ratcheting direction, wherein the body of the barrel ratchet flexes to lock the mandrel spline and housing spline for co-rotation in a driving direction, and the barrel ratchet flexes to separate at least one of the barrel ratchet's internal or external teeth from the mandrel spine or housing spline respectively to release the mandrel spline and housing spline and enable relative rotation.

BRIEF DESCRIPTION OF THE DRAWINGS

[Para 11] Figure 1a is a one quarter section elevation view of a hydraulic running tool having secondary mechanical release and a barrel ratchet clutch accordingly to an embodiment of the invention;

[Para 12] Figure 1b is a cross-section of the tool of Fig. 1a along lines 1b-1b illustrating the barrel ratchet-type clutch between the mandrel and the upper drive housing;

[Para 13] Figures 2a-7 are cross-sectional views of an embodiment of the running tool according to Fig. 1a illustrating latches and hydraulic release apparatus. Each view is shown in the context of and relative to a liner hanger so as to illustrate stages of operation, more particularly:

[Para 14] Fig. 2a illustrates the running tool before hydraulic release;

[Para 15] Fig. 2b is a closer view of the downhole latch housing;

[Para 16] Fig. 2c is a closer view of the uphole housing;

[Para 17] Fig. 2d is a cross-section of the tool according to Fig. 2a taken along lines 2d-2d and illustrating the latch segments in a radially outward latched position;

[Para 18] Fig. 3 illustrates hydraulic actuation for release of the latch cage and latch segments;

[Para 19] Fig. 4a illustrates pickup of the mandrel for release of the latches from the liner hanger;

[Para 20] Fig. 4b is a cross-section of the tool according to Fig. 4a taken along lines 4b-4b and illustrating the latch segments in a radially inward un-latched position;

[Para 21] Fig. 5 illustrates the mandrel free from the liner hanger for confirming released pick-up weight;

[Para 22] Fig. 6 illustrates set-down for rotational coupling with the liner hanger while released therefrom;

[Para 23] Fig. 7 illustrates release and retrieval of the running tool;

[Para 24] Figures 8a - 14 are cross-sectional views illustrating another embodiment of the running tool according to Fig. 1a showing mechanical release of the tool. Again, each view is shown relative to a liner hanger so as to illustrate various stages of operation:

[Para 25] Fig. 8a illustrates the running tool before mechanical release;

[Para 26] Fig. 8b illustrates is a cross-section of the tool according to Fig. 8a taken along lines 8b-8b and illustrating the clutch ring and J-Slot in a load supporting position for supporting the mandrel from the upper drive housing;

[Para 27] Fig. 9a illustrates a ¼ turn left hand (LH) rotation of the mandrel for axial manipulation of the mandrel for enabling release of the latch segments;

[Para 28] Fig. 9b illustrates is a cross-section of the tool according to Fig. 9a taken along lines 9b-9b and illustrating the clutch ring and J-Slot in a

disengaged position with shear screws sheared for enabling mechanical release of the latch shoulders and latch segments;

[Para 29] Fig. 10 illustrates set down of the mandrel for shifting the mandrel downhole relative to the latch cage, releasing the latch segments;

[Para 30] Fig. 11 illustrates further set down of the mandrel, bottoming the range of motion of the upper drive housing and clutch ring, for ensuring release of the latch segments;

[Para 31] Fig. 12 illustrates pickup of the mandrel free from the liner hanger for confirming release of the latch segments through reduced pick-up weight;

[Para 32] Fig. 13 illustrates set-down for right hand (RH) rotational coupling with the liner hanger while remaining axially released therefrom;

[Para 33] Fig. 14 illustrates retrieval of the running tool from the liner hanger;

[Para 34] Figures 15a – 17b are cross-sectional partial side views and end views respectively of the mandrel with integrated mandrel spline, the barrel ratchet and the upper drive housing respectively, more particularly

[Para 35] Figs. 15a and 15b are cross-sectional partial side views and end views respectively of the mandrel with integrated mandrel spline;

[Para 36] Figs. 16a and 16b are cross-sectional side and end views of the barrel ratchet with internal and external teeth;

[Para 37] Figs. 17a and 17b are cross-sectional side and end views of the upper housing drive nut with an integrated housing spline;

[Para 38] Figures 18a and 18b illustrate two isometric views of an embodiment of the barrel ratchet having with internal and external teeth illustrating the alternating end axially-slotted cylindrical body;

[Para 39] Figures 19a and 19b are cross-sectional end views of the clutch comprising the mandrel spline, barrel ratchet and housing spline coupled to first illustrate RH rotation of the mandrel in a locked drivable position to enable the mandrel to rotate the housing (Fig. 19a), and secondly to illustrate left hand (LH) rotation of the mandrel in a ratcheting released position (Fig. 19b) respectively;

[Para 40] Figures 20a-20c are partial cross-sectional end views of the clutch operations, Fig. 20a corresponds to Fig. 19a, Fig. 20b corresponds to Fig. 19b and Fig. 20c illustrates a rest position with the flexibility range of the barrel ratchet body radial motion being evident; and

[Para 41] Figs. 21a and 21b are partial cross-sectional end views of the clutch operations using an optional embodiment corresponding to the operations illustrated in Figs. 20a and 20b, wherein the orientation of the housing spline and external teeth are oriented opposite to that of the embodiment of Figs. 19a,20a and 19b,20b respectively.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[Para 42] RUNNING TOOL

[Para 43] In one embodiment of the invention, and shown generally in Fig. 1a,running tool 5 is provided featuring hydraulic release with optional backup mechanical release and a uni-directional torque clutch that provides premature release protection by dampening anti-backlash and over-rotation as shown in Fig. 1b. Such features are applied in downhole operational circumstances, including for releasable coupling with and running in and release of a liner hanger (not shown). Running tools incorporating the present invention can be applied for releasable connection tubular portions of other downhole tools and to greatest effect with tools that would be rotated and released and preferably rotated once released. The preferred embodiment is described in the context of running in, release and rotation, such as during the process of cementing of a liner hanger.

[Para 44] The running tool 5, liner hanger and depending new liner are run downhole to a setting depth, typically with the liner hanger adjacent the downhole end of the previous casing. The liner hanger is hydraulically set to hang from the previous casing. Prior to commencing cementing of the new liner, it is preferable to ensure the running tool 5 is released from the liner

hanger. The running tool 5 is hydraulically released as described herein and in another embodiment of the present invention, should the hydraulic release fail, the running tool 5 is released using an integrated backup mechanical release. Release can be confirmed with a pickup of the string and running tool. Once released the running tool 5 of the present invention further enables rotation of the running tool 5 for drivably rotating the set liner hanger and new liner while cement is circulated.

[Para 45] Turning to one embodiment of the hydraulic release running tool 5, and with reference to Figs. 1a, 2a and 2b, a running tool 5 generally comprises a mandrel 10 suspended from a drill string (not shown). For convenience, figures represented in landscape format are oriented with uphole to the left.

[Para 46] The liner hanger 13 hangs from the mandrel 10 through a releasable latch between the mandrel 10 and the bore of the liner hanger 13. The mandrel 10 is prevented from pushing through the liner hanger 13 using an uphole drive housing 11 which engages an uphole end of the liner hanger 13.

[Para 47] More particularly, the mandrel 10 extends through an uphole drive housing 11 and through a downhole housing 12. The drive housing 11 enables co-rotation of the mandrel 12 and the liner hanger 13 (a tubular uphole end of a liner hanger assembly illustrated in Fig. 2a). The downhole housing 12 releaseably connects the liner hanger 13 and the mandrel 10.

[Para 48] More specifically with reference to Fig. 2a and 2b, the uphole drive housing 11 comprises a locking cylinder 20 having a drive face 21 at a downhole end which is profiled for drivable connection with a complementary drive face 22 at an uphole end of the liner hanger 13. The sleeve 20 is biased axially downhole using a spring 23 for urging the drive face 21 into engagement with the liner hanger 13. Preferably, the complementary profiles of the drive housing and liner hanger drive faces 21,22 are castellations as one means for enabling a drivable rotational coupling.

[Para 49] The drive housing 11 is co-rotatable with the mandrel 10 for driving the liner hanger through a non-circular interface 24 which prevents relative rotation of the sleeve 20 and mandrel 10 yet enables spring-loaded axial

movement of the sleeve 20 thereon. Preferably, means for co-rotating the drive housing 11 with the mandrel 10 comprises a clutch 25 as described below in greater detail in the context of a mechanical release apparatus for the tool 5.

[Para 50] The downhole housing 12 comprises a latch cage 12a and a hydraulic housing 12b, both of which are sized to fit into an uphole bore of the liner hanger 13. A plurality of circumferentially-spaced latch segments 30 are operable through ports 31 in the latch cage 12a for alternately engaging and disengaging a latch profile 32 with a cooperating and receiving profile 33 in the uphole bore of the liner hanger or other intermediate tubular, uphole of the liner hanger. The latch segments 30 are biased inwardly toward the mandrel 10 by a spring 34. The latch cage 12a is temporarily restrained to the mandrel 10 using shear screws 29. The latch segments 30 are releasable from the liner hanger 13 under either hydraulic or mechanical release operations.

[Para 51] The latch segments 30 are normally supported radially from the mandrel 10 and axially in the engaged position for running in due to the axial positioning of the latch cage 12a. The weight of the liner hanger 13 typically hangs from the latch segments 30 during running in. Further, once the liner hanger 13 is set, then set down weight on the mandrel 10 is normally supported upon the liner hanger 13 through the uphole housing and drive faces.

[Para 52] Each latch segment 30 is supported axially in the latch cage 12a. Axial movement of the latch segments 30 alternately position the latch segments in a radially recessed position with respect to the mandrel 10 or a radially extended position. Control of the axial position of the cage 12a controls whether the latch segments are in the engaged (Fig. 2d) or disengaged position (Fig. 4b).

[Para 53] One embodiment enabling alternate recessed and extending positions of the latch segments is to initially support the latch segments 30 radially outward in an engaged position on ribs 40 extending radially from the mandrel 10 and to subsequently release the latch segments when misaligned from the ribs 40. Greater radial movement is further aided by fitting the latch

segments 30 with corresponding ribs 41 extending radially inwardly. When the mandrel ribs 40 and latch segment ribs 41 are axially aligned, the latch segment 30 is positioned at its maximal radial extent and is in the engaged position. The ribs 40 and 41 have a limited axial extent. When the ribs 40,41 are axially misaligned either uphole or downhole, the latch segments 30 can retract radially to the mandrel 10 to a minimal radial extent and are in the disengaged position.

[Para 54] The latch cage 12a is primarily supported against downhole movement by latch shoulders 35 releasably engaged with and supported on the mandrel 10. The latch shoulders 35 engage the mandrel 10 through an annular profile 36 which engages corresponding annular profile 37 formed in the mandrel. As long as the latch shoulders 35 are retained radially inwards against the mandrel 10, the latch shoulders 35 are capable of supporting the entire hanging weight. The hydraulic housing 12b aids in retaining the latch shoulders 35 against the mandrel 10. Relative movement of the mandrel 10 and the latch cage 12a either uphole or downhole releases the latch segments 30 from the liner hanger 13.

[Para 55] In one embodiment, this relative axial movement is through hydraulic release of support from beneath the latch cages 12a through hydraulic manipulation of the downhole housing 12b resulting in release and removal of the latch shoulders 35 for enabling downhole movement of the mandrel 10 relative to the latch cage 12a.

[Para 56] Alternatively, relative axial movement of the latch cage 12a and mandrel 10 is through manipulation of the uphole housing 11 for freeing the mandrel 10 and enabling forcible movement of the mandrel relative to the latch cage 12a during actuation of the backup mechanical release. As shown in Figs. 2a,2c, normally downhole movement of the uphole housing 11 is arrested by a resting engagement of the uphole housing 11 onto a portion of the subject tool, in this case the drive face 22 of the liner hanger 13. The mandrel 10 has limited capability for axial uphole movement relative to the uphole housing 11 due to clutch ring 70 which is releasably restrained to the mandrel 10 and to the uphole housing 11. The clutch ring 70 has

circumferentially segmented and radially-inward profiles 71 which mate with co-operating a circumferentially segmented annular profiles 72 on the mandrel which are releasable upon indexed, relative rotation. The clutch ring has radial dogs 73 which are rotationally restrained in axial slots 74 in the uphole housing 11 with a dog and spline arrangement which permits axial movement. The axial slots 74 have a stop 75 which limit the axial extent of the movement of the clutch ring's dogs 73.

[Para 57] HYDRAULIC RELEASE

[Para 58] More specifically, and with reference to Figs. 2a-2d and Figs. 3-7, the hydraulic release aspects of the running tool 5 are illustrated. The hydraulic release embodiment of the present invention implements means for release of support from beneath the latch cage 12a, enabling axial misalignment of the mandrel ribs 40 and latch segment ribs 41 for permitting the latch segments 30 to retract radially inward toward the mandrel 10 and thereby releasing the latch from the liner hanger 13.

[Para 59] With reference to Figs. 2a,2b, the mandrel 10 is releaseably connected to the liner hanger 13 such as for running in. The latch cage 12a is supported by the latch shoulders 35 which are profiled to normally mate with complementary profiles in the mandrel 10. The latch shoulders 35 are retained to the mandrel 10 with the hydraulic housing 12b forming a sleeve or locking cylinder 50. A piston annulus 51 is formed between the locking cylinder 50 and the mandrel 10. The locking cylinder 50 has an uphole end 52u which, when axially positioned adjacent the latch shoulders 35, retains each latch shoulder 35 to the mandrel 10 with the profiles 36,37 engaged. When the locking cylinder's uphole end 52u is repositioned downhole of the latch shoulders 35 (Fig. 4a), the shoulders are free to release from the profiles 36,37 and become incapable of supporting axial load any longer.

[Para 60] The piston annulus 51 also forms an annular fluid cylinder having a fluid port 49 formed in the mandrel 10 between the mandrel's fluid bore 9 and the piston annulus 51. The piston annulus 51 is sealed between the mandrel 10 and the locking cylinder 50 at an uphole seal 53 above the port 49. An annular piston 55, retained temporarily by a shear screw 56, is axially movable

in the piston annulus 51 in response to pressure at the port 49. The extent of movement of the annular piston 55 is delimited by contact between a radially outward shoulder or uphole stop 58u protruding from the mandrel 10 below the latch shoulders 35, and a radially inward shoulder or downhole stop 58d formed adjacent a downhole end 52d of the locking cylinder 50. The locking cylinder 50 is movable axially on the mandrel 10, temporarily restrained with shear screws 59, so that contact and force from the annular piston 55 acting on the downhole stop 58d results in downhole movement of the locking cylinder 50.

[Para 61] A shown in Fig. 4a, resulting downhole movement of the locking cylinder 50 releases the radial support of the latch shoulders 35 and the mating profiles 36,37 disengage, which in turn releases axial support of the latch cage 12a. The maximum downhole movement of the locking cylinder 50 is limited by contact of the downhole stop 58d and a further stop 61 at a bottom sub 62 of the mandrel 10.

[Para 62] As a precautionary measure, in an environment of variable pressure and mandrel manipulation, both the annular piston 55 and the locking cylinder 50 are temporarily restrained from premature movement under such pressures using shear screws 56, 59 respectively, shearable under pressures less than hydraulic actuation pressures.

[Para 63] Operationally, as shown in Figs. 2a, 2d, 3 – 7, the latch segments 30 are hydraulically released. The liner hanger 13 is actuated through conventional means and is axially immovable in preparation for downhole operation such as cementing. Initially, as shown in Fig. 2a and 2d, the latch segments 30 remain radially extended and engaged with the liner hanger 13 after running in. The latch segments 30 are retained in the engaged position by the latch cage 12a. The latch cage 12a is supported axially on the latch shoulders 35 which are axially supported on the mandrel 10 as long as they are restrained radially thereto by the uphole end of the locking cylinder 50. The locking cylinder 50 is restrained from unexpected axial motion by its shear screws 59. The annular piston 55 is also in an idle, uphole position, restrained by the shear screws 56.

[Para 64] With reference to Fig. 3, under increased fluid pressure in the bore 9, the annular piston 55 shears free of shear screws 56, moves downhole and engages the downhole stop 58d of the locking cylinder 50. Due to the contact of the piston or as a result of increased pressure and piston force against the downhole stop 58d, shear screws 59 are sheared, enabling downhole movement of the locking cylinder 50. The locking cylinder 50 moves axially to rest against stop 61. As a result of the downhole axial movement of the locking cylinder 50, the latch shoulders 35 are no longer restrained to the mandrel 10, removing any support for the latch cage 12a.

[Para 65] With reference to Fig. 4a, while the latch shoulders 35 may fall free of the mandrel 10 of their own accord, release is assured when the mandrel 10 is picked up as shown. The mandrel 10 shears the assembly screws 29 from the latch cage 12a as the latch segments 30 initially resist pickup; being still engaged with the immovable liner hanger 13. The latch shoulders 35 are released from the mandrel 10, removing support from the latch cage 12a so that the latch segments retract radially to the mandrel 10 as the ribs 40,41 mesh.

[Para 66] As shown in Fig. 5, the operator continues to pick-up the running tool mandrel 10 to confirm release from the liner hanger 13 through sensing of a reduced pickup weight. The drive housing 11 drive face 21 become disengaged from the liner hanger 13 drive face 22. The latch profile 32 of the latch segments 30 is clearly disengaged from the cooperating and receiving profile 33 of the liner hanger 13.

[Para 67] With reference to Fig. 6, the running mandrel 10 tool is set back down for operations. The latch cage 12a and latch segments 30 are no longer supported by the latch shoulders 35 and cannot supportably re-engage the liner hanger 13, ensuring retrieval of the running tool at completion of the operations. The drive face 21 of the uphole drive housing 11 re-engages the drive face 22 liner hanger 13 for enabling co-rotation of the mandrel 10, drive housing 11 and rotatable liner hanger 13. The mandrel 10 is supported by the uphole drive housing 11.

[Para 68] At Fig. 7, the running tool 5 is retrieved by picking up at the mandrel 10, shown as being retrieved through a tie-back receptacle 99 attached atop the liner hanger.

[Para 69] MECHANICAL RELEASE

[Para 70] With reference to Figs. 8a - 14, the latch segments 30 may be mechanically released, typically as a backup system as a result of some failure of the hydraulic release system. Simply, the mandrel 10 is mechanically manipulated to be shifted downhole to release the latch cage 12a through actuation of components as introduced for the hydraulic release embodiment above. Note that the piston 55 and locking cylinder 50 need not be actuated or sheared from their screws 56, 59 respectively to mechanically actuate the tool 5.

[Para 71] With reference to Figs. 2c,8a,8b and 9b, the uphole housing 11 further comprises a clutch ring 70 sandwiched in a clutch annulus 80 between an uphole end 76 of the uphole housing's locking cylinder 20 and the mandrel 10. The clutch ring 70 is normally supported from the mandrel 10 upon facing profiles 71,72 between the mandrel 10 and the uphole housing 11. The profiles 71,72 comprise cooperating circumferentially segmented clutch upsets 81,82 extending radially from each of the clutch ring 70 and the mandrel 10 respectively forming circumferentially spaced axial passages 83 therebetween.

[Para 72] Normally, the mandrel 10 cannot pass axially through the clutch ring 70, the clutch ring being supported by the uphole housing 11, and the uphole housing 11 is resting on an upper end of the liner hanger 13 at the drive faces 21,22.

[Para 73] As shown in Figs. 2c, 8b and 9b, an indexed relative rotation of the mandrel 10 relative to the clutch ring 70 is used to align cooperating clutch upsets 81,82 and axial passages 83 therebetween so as to enable the mandrel 10 to be lowered axially through the clutch ring 70 and thus having sufficient range of axial motion to move through the latch cage 12b to release the latch segments 30. So as to align the clutch upsets 81,82 and axial passages 83, the extent of relative rotation is controlled or delimited using an arrangement

of a pin 85 and J-slot 86 acting between the mandrel 10 and clutch ring 70. Two opposing and redundant pins and J-slot 85,86 arrangements are shown. Additional means and safeguards are provided to avoid accidental actuation of the mechanical release as described later.

[Para 74] As shown in the particular embodiment, the J-slot 86 is located in the mandrel 10 adjacent the clutch ring 70. Accordingly, the corresponding pin 85 is shown extending radially inwardly from the clutch ring 70 for engaging the J-slot 86. The J-slot has a circumferential portion 87 which enables pin movement during indexed rotation. The J-slot 86 further comprises an axial portion 88 extending uphole from the circumferential portion 87 so as to enable axial movement of the pin 85 and clutch ring 70 when aligned.

[Para 75] Thus, the mandrel 10 is rotatable using LH rotation relative to the clutch ring 70, uphole housing 12a and liner hanger 13, as the pin 85 follows the circumferential portion 87. As illustrated with the particular clutch upsets 81,82 shown, after ¼ turn of rotation, when the pin 85 reaches the axial portion 88 of the J-slot 86, each clutch upsets 81 and 82 aligns with an axial passage 83 and thus can move axially downhole relative to the clutch ring 70 and uphole drive housing 11.

[Para 76] As shown in Fig. 2c, each ring-side clutch upset 81 is formed with a plurality of annular grooves 89 for forming a plurality of load support shoulders extending radially inwards. Each mandrel-side clutch upset 82 is also formed with a plurality of annular grooves 89 for forming a plurality of load support shoulders. When the pin 85 resides in the circumferential portion 87 of the J-slot, the annular grooves 89 of the clutch upsets 81,82 are threadably engaged for bearing liner hanging loads.

[Para 77] For a ¼ turn LH rotation actuation of the mandrel, opposing ¼ turn clutch upsets 81,82 and axial passages 83 are implemented to utilize a high hanging load capability. Other arrangements and numbers of clutch upsets can be applied to releasably support the mandrel 10 from the clutch ring 70.

[Para 78] With the ability to mechanically release the uphole housing 11 from the mandrel 10, the mandrel can be shifted through the latch cage 12a for release of the latch segments 30.

[Para 79] In operation, as shown in Fig. 2a and wherein the hydraulic release has failed in Figs. 8a, 8b, the latch cage 12a and latch segments 30 remain retained in the engaged position by the latch shoulders 35 which are in turn supported on the mandrel 10 and continue to be restrained thereto by the uphole end 52u of the locking cylinder 50.

[Para 80] Having reference to Figs. 9a, 9b, a ¼ turn LH rotation of the mandrel shears screws 90 and repositions the pin 85 to rest at the end of the circumferential portion 87 and aligned with the axial portion 88 of the J-slot 86, aligning the clutch upsets and axial passages 81,83 and 82,83 for permitting the uphole drive sleeve 20 to be moved uphole relative to the mandrel 10 and thus relative to the latch cage 12a. The clutch ring 70 moves to an uphole position to engage and stop at a downhole facing shoulder 91 on the mandrel 10; the clutch ring 70 being biased into engagement with the mandrel's shoulder 91 by the spring 23 positioned between the clutch ring 70 and the drive face 21 of the uphole housing 11.

[Para 81] As shown in Fig. 10, once the clutch ring 70 has been disengaged from the mandrel 10 and moved to the uphole position, the mandrel can be set down to shear screw 29 retaining the latch cage 12a. As shown in Fig. 11, further setting down of the mandrel 10 compresses the spring 23, shifting the uphole housing 11 about the dogs 73 of the clutch ring 70, and forces the mandrel through the latch cage 12a and releases the latch segments 30 to the radially inward released position.

[Para 82] As shown in Fig. 12, the mandrel 10 is then picked up to lift the released running tool 5, disengaging the drive faces 21,22 and to enable the operator to sense a reduction in pickup weight, confirming that the running tool 5 has been released from the liner hanger 13.

[Para 83] As was disclosed for the hydraulic operation and shown similarly at Fig. 13, while the running tool 5 is free from the liner hanger 13, the running tool 5 is again set down again to re-engage the drive faces 21,22 and to

permit co-rotation of the running tool 5 and the liner hanger 13 such as is sometimes desirable during cementing operations.

[Para 84] Finally, as shown in Fig. 14, once the downhole operations are completed, the released running tool 5 is picked up for retrieval from the liner hanger 13 and wellbore.

[Para 85] BARREL RATCHET

[Para 86] With reference to Figs. 2c, and 16a - 21b, in some instances, as is the case for the mechanical release of the one embodiment of the running tool 5, it is desirable to provide a robust one-way clutch 25, capable of the transmission of high torque through co-rotation in a primary driving direction and release in the other ratcheting direction. While applicable to many other instances where a clutch 25 is required in high torque, uni-directional implementation, the present invention applies the principles of a novel barrel ratchet 101 within a ratchet annulus 102 formed between the mandrel 10 and the uphole housing 11 so as to impart torque and right hand (RH) rotation from the running tool mandrel 10 into the liner hanger 13 and any liner depending therefrom.

[Para 87] Further, as discussed should it be necessary to enable the mechanical release function of the mandrel 10 and clutch ring 70, it is desired to use the clutch 25 to enable left hand (LH) rotation of the mandrel 10 relative to the uphole drive housing 11 or sleeve 20.

[Para 88] The illustrated clutch 25 is enabled for RH locked and drivable co-rotation of the housing 11 as this is the usual embodiment used for downhole tool operation. Using a reversed orientation of the mechanical components, the clutch 25 is equally useful and can be implemented on the opposite rotational sense in tools or operation where the driving co-rotation is in the opposing LH direction.

[Para 89] With reference to the embodiment shown in Figs. 10, 15a-20b, such a clutch 25 is implemented for enabling RH rotation of the mandrel 10 to drive RH co-rotation of the housing 11 and conversely LH rotation of the mandrel 10

results in a ratcheting, or substantially free, rotation of the mandrel relative to the housing 11.

[Para 90] The clutch 25 comprises external mandrel splines 103 formed on the mandrel 10 (Figs. 15a,15b) and extending into the ratchet annulus 103 and internal housing splines 104 formed in the uphole housing 11 (Figs. 15a,15b, 17a,17b) and which also extend into the ratchet annulus 102. As shown in Fig. 10, the mandrel splines 103 have sufficient axial extent to permit the uphole housing 11 to move axially throughout an operational range while maintaining at least some overlap of the mandrel and housing splines 103,104 and thus maintain co-rotation.

[Para 91] Turning to Figs. 16a,16b, and 19a,19b, the barrel ratchet 101 is shown residing in the ratchet annulus 102 formed between the mandrel and housing splines 103,104. Typically, through torsional impetus, the barrel ratchet 101 can be elastically alternated between a radially expanded (ratcheting) position and radially contracted (locked) position.

[Para 92] With reference in more detail to Figs. 19a,19b, the mandrel and housing splines 103,104 form profiled teeth 103t,104t. The barrel ratchet 101 has a substantially cylindrical body 110 upon which is formed profiled internal teeth Ri and external teeth Ro.

[Para 93] With reference also to Fig. 20a, each tooth 103t,104t of the mandrel and housing splines 103,104 and the barrel ratchet teeth Ri,Ro form at least two faces Fi,Fo which are asymmetrical, one of faces Fi or Fo having a ramped face, angled somewhat from a tangent, and at least one of either Fo or Fi having a substantially upstanding face which is oriented more closely to a radial. The mating faces Fi,Fo of the mandrel spline's teeth 103t and the barrel ratchet's internal teeth Ri are complementary and the mating faces of the housing spline's teeth 104t and barrel ratchet's external teeth Ro are complementary as set forth in greater detail herein. Each face Fi. Fo can be characterized as having a ramped and an upstanding face; the ratchet's external teeth Ro having a ramped face For and an upstanding face Fou; and the ratchet's internal teeth Ro having a ramped face Fir and an upstanding face Fiu.

[Para 94] As shown in Figs. 19a and 20a, when contracted, the body 110 of the barrel ratchet 101 is caused to contract radially in the ratchet annulus 102 so as to engage its internal teeth Ri with the mandrel spline teeth 103t while the barrel ratchet's external teeth Ro continue to remain engaged with the housing spline teeth 104t, thereby locking the mandrel and housing splines 103,104 for co-rotation. Preferably the body 110 of the barrel ratchet 101 normally resides in an elastically contracted state for normally gripping the mandrel's spline 103 through the internal teeth Ri and mandrel spline teeth 103t. Right hand rotation of the mandrel and housing spline 103,104 engages tooth faces Fi,Fo. Lash between the barrel ratchet 101 and housing spline 104 closes for enabling RH rotation of the housing 11. In the particular embodiment of Figs. 15a - 20c, the orientation of the barrel ratchet teeth Ro driving the housing spline 104 form mating ramps which act to impose radial contracting forces on the flexible body 110 of the barrel ratchet 101, superadding to the force of the grip between the mandrel spline 103 and barrel ratchet 101. Optionally, as shown in Figs. 21a and 21b, the barrel ratchet 101 is also effective wherein the interface of barrel ratchet teeth Ro and housing spline 104 is more upstanding or radially oriented. The orientation between the barrel ratchet's external teeth Ro and the housing spline 104 is such that radially outward wedging forces are still avoided during the driving rotation and thus separation forces of the mandrel spline 103 and barrel ratchet internal teeth Ri is also avoided.

[Para 95] As shown in Fig. 19b, when the body 110 of the barrel ratchet 101 is expanded radially, the housing spline 104 radially accepts the external teeth Ro sufficiently so that the internal teeth Ri are released from the teeth 103t of the mandrel spline 103 for enabling relative rotation therebetween.

[Para 96] The barrel ratchet 101 is a unitary member generally like a gear. The body 110 is flexible so that the root diameter of the teeth Ro, Ri can be varied which enables the expanded and contracted positioning of the tip diameters of the internal and external teeth Ri,Ro. The radial working depth of the mandrel spline 103 is less than the radial working depth of the housing spline 104. Accordingly, throughout elastic expansion and contraction of the

barrel ratchet's body 110, the external teeth Ro remain locked for co-rotation with the housing spline teeth 103t while the internal teeth Ri alternate between engagement and disengagement with the mandrel spline's teeth 103t.

[Para 97] As illustrated, in a case wherein the axial extent of the barrel ratchet 101 is wholly within the axial extent of the ratchet annulus 102 formed by the mandrel and housing splines 103,104 , the entire axial length of the barrel ratchet 101 is capable of expansion and contraction to enable ratcheting. It is possible that a barrel ratchet 101 need only be partially engaged in a ratchet annulus 102 and therefore only a portion of the body 110 needs to be flexible.

[Para 98] Best shown in Figs. 18a,18b, for enabling a flexible root diameter of the internal and external teeth Ri,Ro, the cylindrical body 110 has a plurality of axially-extending slots 120 spaced periodically about its circumference. For enabling flexibility of the barrel ratchet body 110 along its entire axial extent, a first set of slots 120,120a extend axially from a first end to terminate adjacent a second end and a second set of slots 120,120b extend axially from the second end to terminate adjacent the first end, the slots of the first and second sets of slots alternating for forming alternating fingers 121 enabling flexible internal teeth Ri and flexible external teeth Ro. A root 122 of each slot 120 is contoured to relieve stress concentrations.

[Para 99] The first and second slots 120a,120b extend axially a distance less than the axial extent of the barrel ratchet 101 so that the barrel ratchet remains unitary or contiguous. The first set of slots 120a are circumferentially indexed from the second set of slots 120b so that the cylindrical body 110 remains unitary and is comprised of flexible fingers 121 of teeth cantilevered from alternating ends of the cylindrical body 110.

[Para 100] With reference to Fig. 20b (ratcheting), when the barrel ratchet 101 is expanded in the ratcheting direction, the diameter of the internal teeth Ri expands sufficiently to enable the internal teeth to slip, ride over or otherwise rotate relative to the mandrel spline 103. With reference to Fig. 20a (driving) and Fig. 20c (neutral), when the barrel ratchet 101 is contracted, the diameter of the internal teeth Ri contracts sufficiently to engage the mandrel spline 103. At rest, the barrel ratchet 101 is elastically biased to grip the mandrel 10.

[Para 101] In the tool embodiment, when the mandrel 10 is rotationally driving (Fig. 20a) the uphole housing 11 in a RH rotation for running in the liner 13, the mandrel spline teeth 103t and internal teeth Ri of the barrel ratchet 100 engage at substantially upstanding faces Fiu. The face Fiu are driving faces and should there be radial forces generated in that contact Fiu, they do not act sufficiently to expand the barrel ratchet 101 and do not separate faces Fiu and thus the clutch is drivably engaged. Preferably, the circumferential orientation of the internal teeth 104t of the housing spline 104 is opposite of that of the mandrel spline's teeth 103t. In other words, the ramped faces Fir of the mandrel spline 103 increase radially outwards as the ramp progresses clockwise while the ramped faces For of the housing spline 104 increasing radially outwards as the ramp progresses counterclockwise. This relative orientation has additional benefit during RH rotation for drivably rotating the uphole housing 11; the force vector between the external teeth ramps For aid to wedge the barrel ratchet 101 onto the mandrel spline 103. Accordingly the faces For also form driving faces to transmit torque from the barrel ratchet 101 to the housing 11. Little supplementary wedging force is generated if the upstanding faces For are substantially radial or at an acute angle.

[Para 102] To release the clutch 25 in opposite hand rotation, the mandrel 10 is rotated in a LH rotation for actuating the mechanical release of the clutch ring 70. The teeth 103t of the mandrel spline 103 engage the internal teeth Ri of the barrel ratchet 101, expanding the body 110 of the barrel ratchet 101 through radial forces generated between the corresponding ramped faces Fir of the teeth 103t of the mandrel spline and the internal teeth Ri of the barrel ratchet. The radial force vector generated by the facing ramps Fir expands the barrel ratchet 101 until the diameter of the internal teeth Ri is greater than the mandrel spline teeth 103t. When the barrel ratchet 101 expands, the external teeth Ro are free to more fully and radially engage the teeth 104t of the housing spline 104.

[Para 103] In another embodiment, as shown in Figs. 21a and 21b, the circumferential orientation of the ramped faces For of the housing spline is the same as that of the mandrel spline Fir which is also increasing radially

outwards as the ramp progresses clockwise. This orientation does not provide as much wedging force as that resulting from the embodiment of Figs. 20a-20c.

[Para 104] PROTECTION FROM ACCIDENTAL RELEASE

[Para 105] Typically downhole components are run in using RH rotation. When running in a liner, there is drag resistance to rotating the liner, causing the liner to rotationally lag the running tool rotation somewhat, elastically winding up the length of elastic liner below the running tool and the length of drill string above the running tool.

[Para 106] Right hand torque starts at the top of the mandrel 10 and is transmitted through mandrel splines 103 to the barrel ratchet 101. The barrel ratchet 101 transmits the RH torque to the drive housing splines 104, the drive housing 11, the liner hanger 13 and down to the bottom of the liner string.

[Para 107] For actuation of the mechanical release and J-slot, LH torque starts at the top of the mandrel 10 and reaches mandrel splines 103 at the barrel ratchet 101. Ratcheting therebetween permits the mandrel 10 to rotate to the left while the drive housing 11 and liner string remain stationary. This should only occur due to deliberate LH rotational actuation by an operator.

[Para 108] Inappropriate LH torque or backlash is generated at the bottom of the liner and travels up the liner string. The LH torque is a result of the RH torque building up in the liner string and then releasing. Such backlash is then transmitted from the liner hanger 13, through the drive housing 11 and splines 104, and to the barrel ratchet 101 which is equivalent to the usual RH torque during running in. The backlash is transmitted to the mandrel splines 103 for transmission up the mandrel 10 to the drill string, where the backlash is dissipated.

[Para 109] The clutch 25 and barrel ratchet 101 prevent the backlash from creating independent LH rotation between the drive housing 11 and the mandrel 10, without the need of shear screws. The ratchet 101 of the present invention is equally responsive for transmitting RH rotation from the uphole

components into the downhole components and for resisting LH rotation from the downhole components into the uphole components.